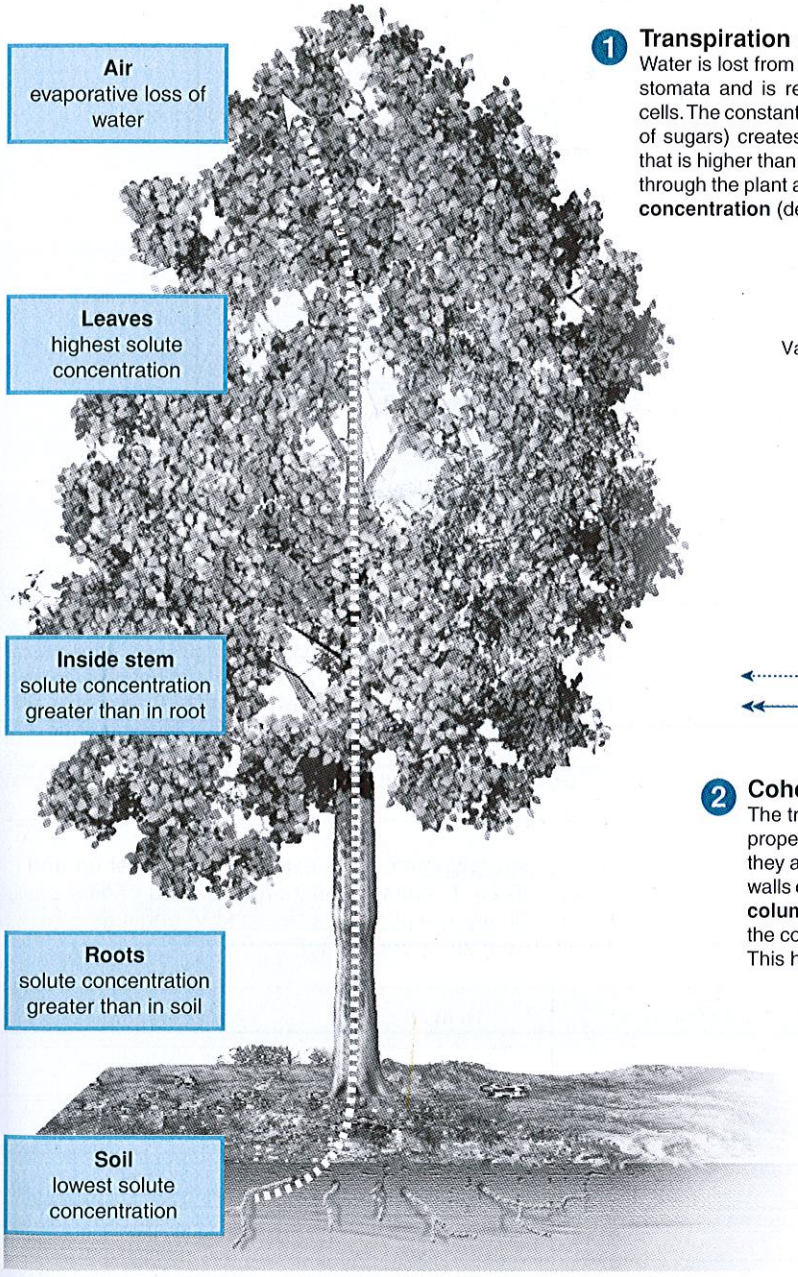
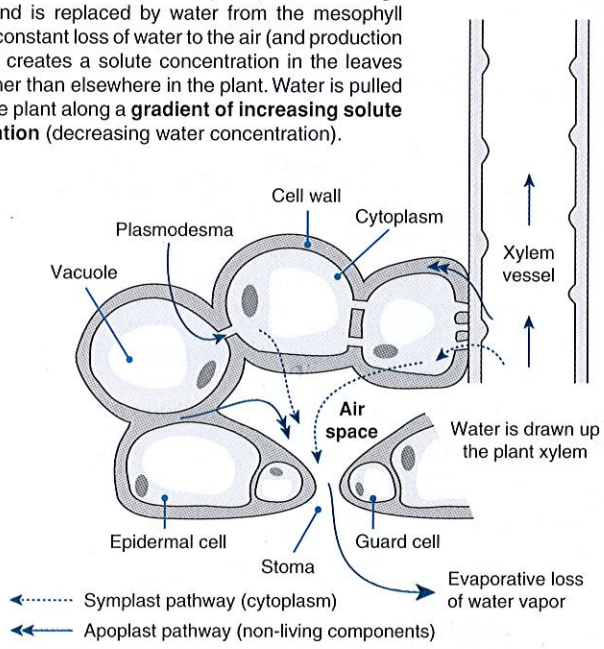
Transpiration in Plants

Plants lose water all the time, despite the adaptations they have to help prevent it (e.g. waxy leaf cuticle). Approximately 99% of the water a plant absorbs from the soil is lost by evaporation from the leaves and stem. This loss, mostly through stomata, is called **transpiration** and the flow of water through the plant is called the **transpiration stream**. Plants rely on a gradient in solute concentration from the roots to the air to move water through their cells. Water flows passively from soil to air along a gradient of increasing solute (decreasing water) concentration. This gradient is the driving force in the ascent of water up a plant. A number of processes contribute to water movement up the plant: transpiration pull, cohesion, and root pressure. Transpiration may seem wasteful, but it has benefits; evaporative water loss cools the plant and the transpiration stream helps the plant to maintain an adequate mineral uptake, as many essential minerals occur in low concentrations in the soil.



1 Transpiration pull

Water is lost from the air spaces by evaporation through stomata and is replaced by water from the mesophyll cells. The constant loss of water to the air (and production of sugars) creates a solute concentration in the leaves that is higher than elsewhere in the plant. Water is pulled through the plant along a **gradient of increasing solute concentration** (decreasing water concentration).



2 Cohesion-tension

The transpiration pull is assisted by the special **cohesive** properties of water. Water molecules cling together as they are pulled through the plant. They also **adhere** to the walls of the xylem (**adhesion**). This creates one **unbroken column of water** through the plant. The upward pull on the cohesive sap creates a tension (a negative pressure). This helps water uptake and movement up the plant.

3 Root pressure

Water entering the stele from the soil creates a **root pressure**; a weak 'push' effect for the water's upward movement through the plant. Root pressure can force water droplets from some small plants under certain conditions (**guttation**), but generally it plays a minor part in the ascent of water.

1. (a) Plants constantly lose water by transpiration. Explain how plants compensate for this: _____

   _____

   (b) Describe one benefit of the transpiration stream for a plant: _____

   _____

2. Briefly describe three processes that assist the transport of water from the roots of the plant upward:

   (a) _____

   (b) _____

   (c) _____

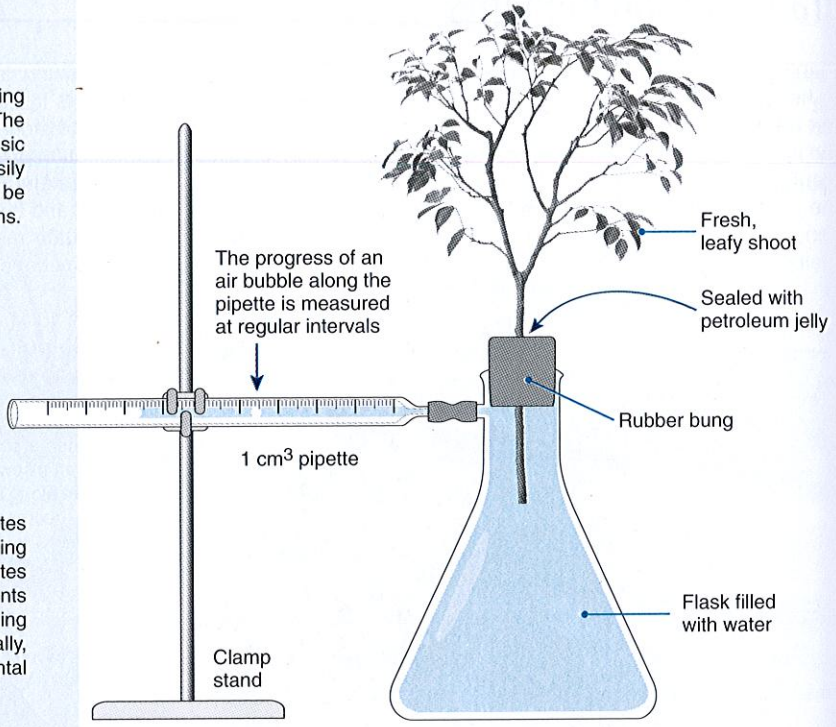
The Potometer

A potometer is a simple instrument for investigating transpiration rate (water loss per unit time). The equipment is simple and easy to obtain. A basic potometer, such as the one shown right, can easily be moved around so that transpiration rate can be measured under different environmental conditions.

Some of the physical conditions investigated are:

- Humidity or vapor pressure (high or low)
- Temperature (high or low)
- Air movement (still or windy)
- Light level (high or low)
- Water supply

It is also possible to compare the transpiration rates of plants with different adaptations e.g. comparing transpiration rates in plants with rolled leaves vs rates in plants with broad leaves. If possible, experiments like these should be conducted simultaneously using replicate equipment. If conducted sequentially, care should be taken to keep the environmental conditions the same for all plants used.



3. Describe three environmental conditions that increase the rate of transpiration in plants, and explain how they operate:

   (a) _____

   (b) _____

   (c) _____

4. The **potometer** (above) is an instrument used to measure transpiration rate. Briefly explain how it works:

   _____

   _____

5. An experiment was conducted on transpiration from a hydrangea shoot in a potometer. The experiment was set up and the plant left to stabilize (environmental conditions: still air, light shade, 20°C). The plant was then subjected to different environmental conditions and the water loss was measured each hour. Finally, the plant was returned to original conditions, allowed to stabilize and transpiration rate measured again. The data are presented below:

Experimental conditions	Temperature (°C)	Humidity (%)	Transpiration (g h^{-1})
(a) Still air, light shade, 20°C	18	70	1.20
(b) Moving air, light shade, 20°C	18	70	1.60
(c) Still air, bright sunlight, 23°C	18	70	3.75
(d) Still air and dark, moist chamber, 19.5°C	18	100	0.05

   (a) Name the control in this experiment: _____

   _____

   (b) Identify the factors that increased transpiration rate, explaining how each has its effect: _____

   _____

   _____

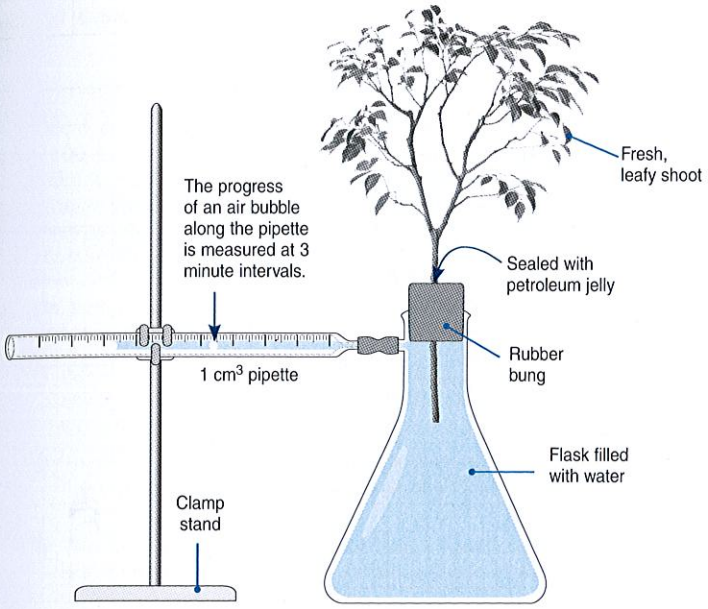
   (c) Suggest a possible reason why the plant had such a low transpiration rate in humid, dark conditions:

   _____

   _____

Investigating Plant Transpiration

Once you have your experimental results (data), it is often helpful to tabulate and graph the information. Graphs and tables display data in a way that makes it easy to see trends or relationships between different variables. Presenting graphs properly requires attention to a few basic details, including correct orientation and labelling of the axes, and accurate plotting of points. This activity describes a plant transpiration experiment and provides guidelines for drawing line graphs. Put these guidelines into practice by graphing the second hand data provided as part of this activity.



The Apparatus

This experiment investigated the influence of environmental conditions on plant transpiration rate. Four conditions were studied: room conditions (ambient), wind, bright light, and high humidity. After setting up the potometer, the apparatus was equilibrated for 10 minutes, and the position of the air bubble in the pipette was recorded. This is the time 0 reading. The plant was then exposed to one of the environmental conditions. Students recorded the location of the air bubble every three minutes over a 30 minute period. The potometer readings for each environmental condition are presented in Table 1 (next page).

The Aim

To investigate the effect of environmental conditions on the transpiration rate of plants.

Background

Plants lose water all the time by evaporation from the leaves and stem. This loss, mostly through pores in the leaf surfaces, is called **transpiration**. Despite the adaptations plants have to help prevent water loss (e.g. waxy leaf cuticle), 99% of the water a plant absorbs from the soil is lost by evaporation. Environmental conditions can affect transpiration rate.

A class was divided into four groups to study how four different environmental conditions (ambient, wind, bright light, and high humidity) affected transpiration rate. A **potometer** was used to measure transpiration rate (water loss per unit time). A basic potometer, such as the one shown left, can easily be moved around so that transpiration rate can be measured under different environmental conditions.

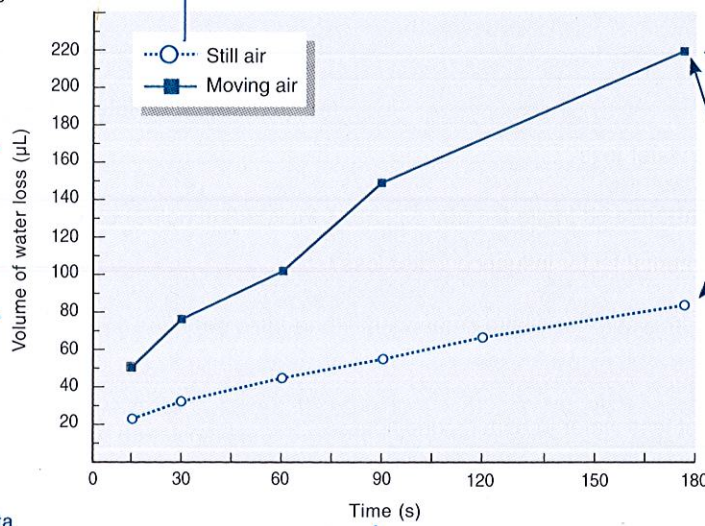
Guidelines for Drawing Line Graphs

Line graphs are used when one variable (the independent variable) affects another, the dependent variable.

Graphs (called figures) should have a concise, explanatory title. If several graphs appear in your report they should be numbered consecutively.

Fig. 1: Cumulative water loss in µL from a geranium shoot in still and moving air.

A key identifies symbols. This information sometimes appears in the title.



Plot points accurately. Different responses can be distinguished using different symbols, lines or bar colors.

Label both axes and provide appropriate units of measurement if necessary.

Two or more sets of results can be plotted on the same figure and distinguished by a key. For a time series, it is appropriate to join the plotted points with a line.

Place the dependent variable e.g. biological response, on the vertical (Y) axis (if you are drawing a scatter graph it does not matter).

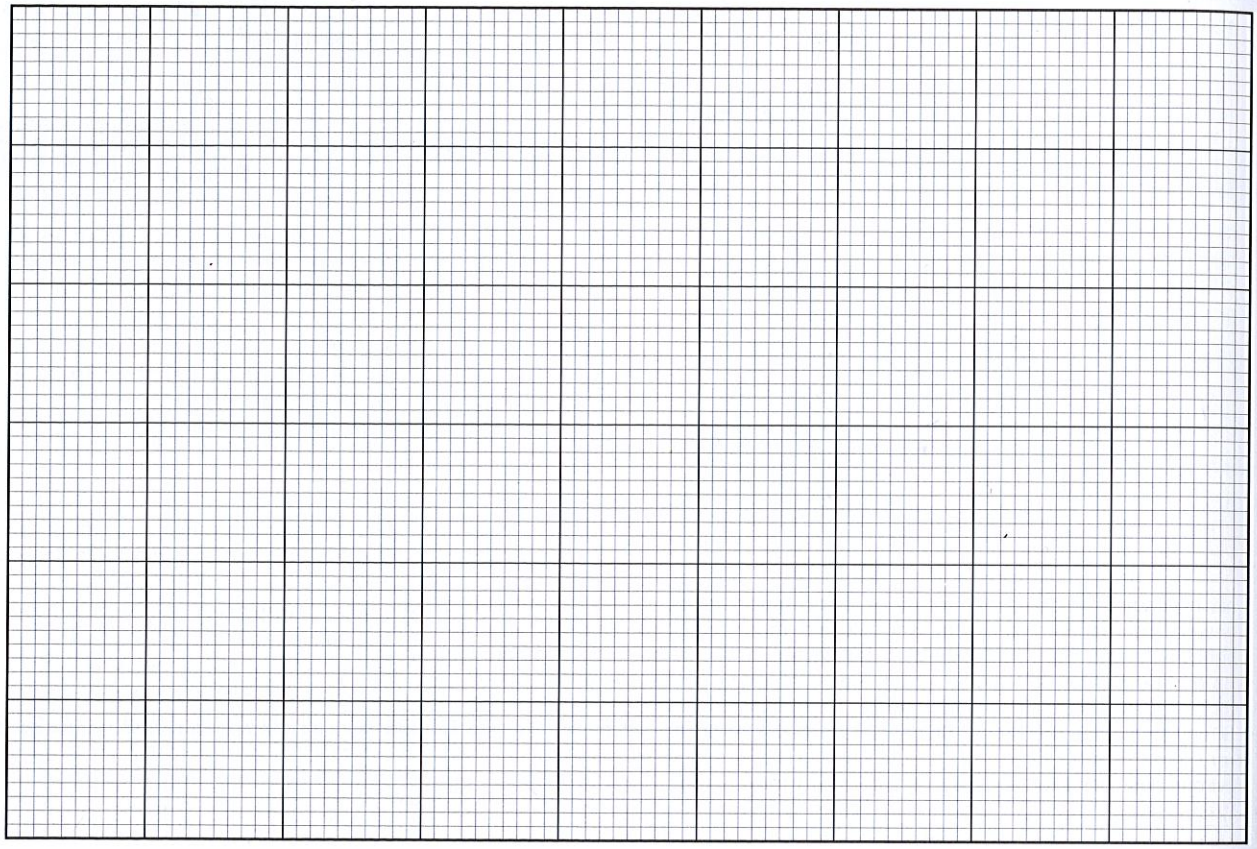
Each axis should have an appropriate scale. Decide on the scale by finding the maximum and minimum values for each variable.

NOTE: The data must be continuous for both variables.

Place the independent variable e.g. time or treatment, on the horizontal (X) axis

Table 1. Potometer readings

Time (min) / Treatment	0	3	6	9	12	15	18	21	24	27	30
Ambient	0	0.002	0.005	0.008	0.012	0.017	0.022	0.028	0.032	0.036	0.042
Wind	0	0.025	0.054	0.088	0.112	0.142	0.175	0.208	0.246	0.283	0.325
High humidity	0	0.002	0.004	0.006	0.008	0.011	0.014	0.018	0.019	0.021	0.024
Bright light	0	0.021	0.042	0.070	0.091	0.112	0.141	0.158	0.183	0.218	0.239



1. (a) Plot the potometer data from Table 1 on the grid provided. Use the guidelines for drawing line graphs on the previous page as a reference if you need help:

   (b) Identify the independent variable: _____

2. (a) Identify the control: _____

   (b) Explain the purpose of including an experimental control in an experiment: _____

   _____

   _____

   (c) Which factors increased water loss? _____

   _____

   (d) How does each environmental factor influence water loss? _____

   _____

   _____

   (e) Explain why the plant lost less water in humid conditions: _____

   _____

   _____

   _____